Reliability of the integrated radiograph-photograph method to obtain natural head position in cephalometric diagnosis

Dvortsin, Dima P.; Ye, Qingsong; Pruim, Gerard J.; Dijkstra, Pieter U.; Ren, Yijin

Published in:
Angle Orthodontist

DOI:
10.2319/010411-2.1

Original Article

Reliability of the integrated radiograph-photograph method to obtain natural head position in cephalometric diagnosis

Dima P. Dvortsin[a,*]; Qingsong Ye[b,*]; Gerard J. Pruim[c]; Pieter U. Dijkstra[d]; Yijin Ren[e]

ABSTRACT

Objective: To introduce a simple and reliable method to reorient lateral radiographs to the natural head position (NHP) according to standardized photographs made at NHP.

Material and Methods: The study has two parts. In the first part, 45 patients were randomly selected from a patient cohort. Photographs (at NHP) and cephalograms from each patient were taken and assessed in two sessions by two observers. The time between the first and the second session was 5 weeks. The repeatability of profile measurements on cephalograms compared with standardized photographs of the same patient was determined; in the second part, the repeatability of three superimposing protocols (ie, the soft tissue N/subnasale line [V-line], the esthetic line [E-line], and a proposed nose best fit line [N-line]) was compared for the reorientation of the cephalogram according to the photographs made at the NHP.

Results: Our results showed that the integration of radiographs and photographs is an objective and reliable method to obtain NHP in lateral cephalograms. The N-line is a reproducible and stable reference line for the reorientation of radiographs to obtain NHP.

Conclusion: Reorientation of radiographs according to standardized photographs made at the NHP is a reliable and objective method to standardize the radiographs at the NHP for cephalometric analysis. The N-line is a reproducible and stable reference line for the reorientation. It is preferred over the V-line or even E-line, especially when the radiographs and photographs are taken at different sessions or at different treatment stages. (*Angle Orthod.* 2011;81:889–894.)

KEY WORDS: Orthodontics; Natural head position; Cephalometrics; True vertical line; Superimposition

INTRODUCTION

To determine the anterior-posterior skeletal relationships by cephalometric analyses, orthodontists have to make a choice between the intracranial and extracranial reference lines.[1–3] Intracranial reference lines, such as the sella-nasion plane and Frankfort horizontal, are widely used.[4] However, the landmarks that determine the intracranial reference lines change continuously during growth and vary among individuals. Therefore, such lines are inherently unreliable and likely to mislead orthodontic diagnosis and treatment planning.[5,6]

Natural head position (NHP) has been proposed as an extracranial reference in orthodontics since the 1950s. The NHP is a standardized position of one's head in an upright head posture with one's eyes focused on a point in the distance at eye level.[6,7] NHP is a stable and reproducible position as it represents the true-life appearance of human beings.[3] Numerous studies have been done on the reproducibility/stability of NHP and have shown positive outcomes, both in short and long intervals.[8–11]

[a] Resident, Department of Orthodontics, University Medical Centre Groningen, University of Groningen, The Netherlands.

[b] PhD Candidate, Department of Orthodontics, University Medical Centre Groningen, University of Groningen, The Netherlands; Department of Orthodontics, West China College of Stomatology, Sichuan University, China.

[c] Instructor, Department of Orthodontics, University Medical Centre Groningen, University of Groningen, The Netherlands.

[d] Professor, Department of Oral and Maxillofacial Surgery, University Medical Centre Groningen, University of Groningen, The Netherlands.

[e] Professor and Chair, Department of Orthodontics, University Medical Centre Groningen, University of Groningen, The Netherlands.

[*] These two authors contributed equally to the work.

Corresponding author: Dr Yijin Ren, Department of Orthodontics, University Medical Centre Groningen, Hanzeplein 1, triade 24, Groningen, Groningen 9700 RB University of Groningen, The Netherlands
(e-mail: y.ren@dmo.umcg.nl)

Accepted: March 2011. Submitted: January 2011.
Published Online: May 4, 2011

Several methods have been used to obtain the NHP for cephalometric diagnosis. The first method is estimated NHP, in which a patient's conventional radiographs or lateral facial photographs are taken and adjusted to his or her NHP by orthodontists. Another technique is registered NHP, in which the head of the patient is orientated to his or her NHP and a marker or a plumb line is used as the true vertical reference before radiographs and photographs are taken.[12,13] Reorientating the radiographs according to photographs with certain reference lines (eg, soft tissue N-subnasale line and E-line) is also a method applied. This method is based on previous studies in which it was found that acquiring the NHP on radiograph is more difficult than on photograph.[11] This difference could be due to ear rods, which force the patient's head in an unnatural tilted position. Also, the nasal support from the cephalostat might disturb the natural position of the head. It has been assumed that it is more likely for the patient to (re)produce the NHP during photograph taking with proper instructions.[2,11] However, large variations in reproducibility have been shown between studies, including the methodology in obtaining NHP and the superimposition of radiographs and photographs.[12,14,15] Some landmarks that define the reference lines (eg, subnasale [V-line] and chin [E-line]) are changing during orthodontic treatment. Therefore, a critical and systematic assessment of the reliability of the method of reorienting radiographs according to standardized photographs made on NHP is necessary.

In the present study, we aim to develop a simple and reliable method to reorient lateral radiographs to NHP according to the standardized photographs made on NHP. For this purpose, the present study has two parts: (1) to determine the reliability of profile measurements on cephalograms compared with standardized photographs of the same patient and (2) to compare the reliability of three superimposing protocols, that is, the soft tissue N/subnasale line (V-line), the esthetic line (E-line), and a proposed nose-best-fit line (N-line).

MATERIALS AND METHODS

Standardized Photographic Setup

To ensure maximal coincidence between the lateral cephalogram with the lateral photograph, a standardized setup was made to maintain the cephalostat in a stable condition. In this setup, the object-film distance was kept to 165 cm, similar to the distance of the object to cathode in the cephalostat (ProMax, DiMax2 Cephalometric Unit, Planmeca, Helsinki, Finland) to prevent any optical distortion of the recorded object. The patient was asked to sit in a chair that was fixed on a marked spot. A rigid camera arm was constructed, giving movement freedom only at the vertical plane or along the rail on the arm itself. Because rotational and tilting movements of the camera were blocked, the patient was always recorded at a 90° angle, as it occurred at the cephalostat. Prior to the study, the edge of the photograph was adapted to a plumb line, using fine adjustment of the developed camera fixation system. Therefore, the edge of the photographs can be considered as the true vertical (TV).

The present study has received institutional approval from University Medical Centre Groningen. Forty-five patients were randomly selected from the patient cohort of Department of Orthodontics, University Medical Centre Groningen, from the period of January until May 2009. Each patient was instructed to keep the teeth gently in occlusion and to look in a mirror. The mirror was situated perpendicular at a distance of 2 m, and the patient was asked to move his or her head up and down to find the most natural and relaxed position, the NHP. The photograph was taken with the soft tissues of the patient fully seen. The photograph and cephalogram of the included subjects were obtained at the same appointment. The cephalogram was obtained while the patient held his or her teeth gently in occlusion and was looking at the same mirror. The ear rods from the cephalostat were adapted to the patient as passively as possible. To exclude any magnification error, a calibrated gauge was fixed at the forehead of each patient (Figure 1). Using Viewbox 3.1.1.9 software (dHAL, Kifissia, Greece), the gauge was measured on screen under high magnification and the photographic image was rescaled accordingly. The same software was used for cephalometric analysis of the cephalograms and the photographic images. Photographs and cephalograms from each patient were assessed in two sessions by two observers. The time between the first and the second session was on average 5 weeks.

Reorientation of the Cephalogram According to the Photographs at the NHP

The purpose of this part was to reorientate the radiograph of a patient according to the photograph taken at the NHP. As the upper part of the facial profile is considered more stable than the lower part,[16] a line was constructed along which the superposition is hypothesized to be reliable and reproducible. This line is the N-line (Figure 1). Because it is automatically drawn through five landmarks along the nasal bridge, its measurement error is assumed to be lower that that of a two-point line. The superposition of a radiograph on a photograph made from the same session from the same patients was performed using this line and point Pronasale. Then, the angle of the N-line to the TV was registered. Again, this was performed twice per tracing

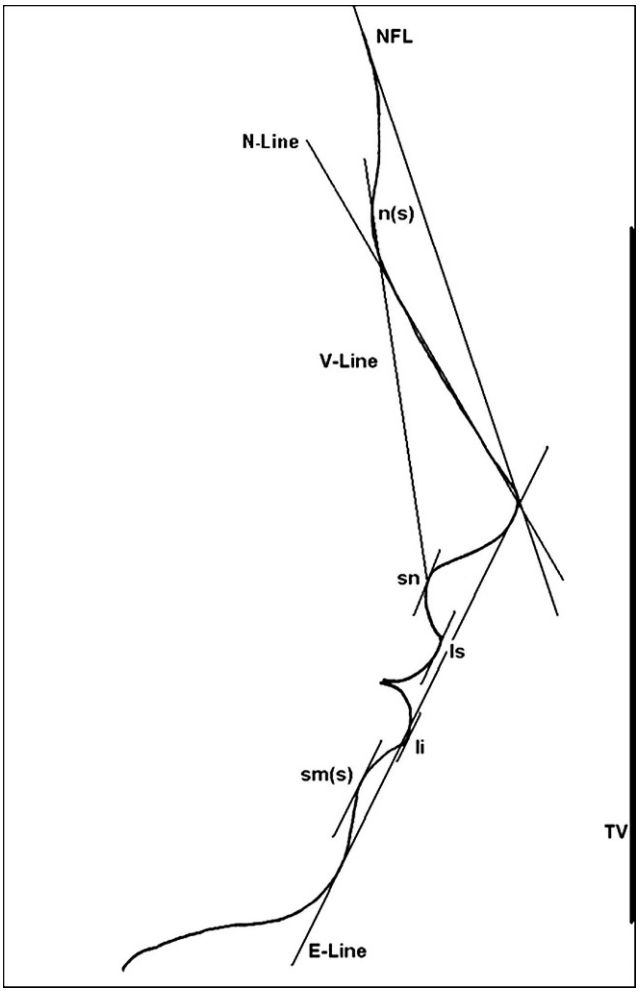

Figure 1. Land markers. n(s) indicates soft tissue nasion; sn, subnasale: the deepest point of the nasolabial curvature; li, labrale inferius: most prominent point of the lower lip; ls, labrale superius: the most prominent point of the upper lip; and sm (s), soft tissue supramentale: the deepest point of the mento-labial sulcus. Reference lines. TV, true vertical; NFL, nose-frontal-line; N-line, nose-best-fit-line; V-line, soft nasion–subnasale; and E-line, nose-chin tangent.

session per observer. The variations were compared with those from the V-line and the E-line to TV.

Statistical Analysis

All measured variables and their definitions are described in Table 1. Reliability coefficients were calculated as measures for interobserver, intersession, and intermethod reliability.[17,18] Reliability coefficients were calculated based on variance components estimated in SPSS. A reliability coefficient of .9 is a minimal requirement for clinical use of a measurement technique.[19]

RESULTS

The descriptive statistics of the cephalometric measurements are presented in Table 2. The interobserver, intersession, and intermethod reliability coefficients for the different facial structures all exceeded .900, except the intermethod reliability for Nasal angle. This means that except for the Nasal angle, all other measurements are interchangeable between the two observers and sessions and even between the radiograph and photograph methods (Table 3). This indicates that reorientation of radiographs according to standardized photographs made at the NHP is a reliable method to standardize the radiographs at the NHP for cephalometric analysis.

The interobserver and intersession reliability coefficients all exceeded .900 for V-angle, E-angle, and N-angle. The intermethod reliability was moderate for all three angles (range, .545–.737). However, N-angle is preferred over V-angle because its confidence intervals had only a very small overlap.[19] The difference between E-angle and N-angle in reliability coefficients is minor (Table 3).

DISCUSSION

NHP has been widely recognized as a better reference than intracranial reference lines for the analysis of craniofacial morphology in orthodontics. Yet in practice, it is rather difficult or unreliable to acquire standardized radiographs at the NHP.[11] In addition, the methods to obtain the NHP on radiographs by post hoc modification are still under debate. The present study presented a new method to reorient radiographs via standardized photographs made at the NHP according to the N-line in obtaining the NHP for radiographs. The proposed method has proven to be simple and highly reliable for obtaining standardized radiographs at the NHP for orthodontic diagnosis, treatment planning, and evaluation of treatment results.

The concept of NHP was introduced to orthodontics in 1956. It is an individual functional physiologic position that has been used in anthropology to study the relationship between function and morphology for centuries and is recognized as the good reference for cephalometric analyses in orthodontics. However, NHP can be influenced by many factors, for example, different photographing postures and methods.[20] It has been observed clinically that because of the earplugs from the cephalostat, patients tend to hold their head in an unnaturally extended or flexed position when radiographs are taken, which would give misleading outcomes. On the contrary, when photographs were taken, patients appear to be more relaxed and NHP can be obtained more easily.[9] Therefore, reorienting radiographs according to standardized photographs is a good and simple method.

Table 1. Measured Variables and Their Definitions

Variable	Definition
Angular variables (degree)	
1. Total facial convexity	Nose-frontal-line to true vertical (NFL-TV)
2. Total facial convexity excluded nose	Soft tissue nasion–subnasale line to true vertical (n(s)–sn-TV)
3. Profile form	Nose-frontal-line to nose-chin tangent (NFL–E-line)
4. Convexity at soft pronasale	Nose-best-fit-line to nose-chin tangent (N-line–E-line)
5. Nasal angle	Nose-frontal-line to true vertical (N-line–TV)
6. Nose front angle	Nose-best-fit-line to nose-frontal-line (N-line–NFL)
Linear variables (mm)	
7. Depth of nasolabial curvature	Subnasale to nose-chin tangent (sn–E-Line)
8. Depth of mental fold	Soft tissue supramentale to nose-chin tangent ($sm_{(s)}$–E-line)
9. Upper lip prominence	Labrale superius to nose-chin tangent (ls–E-line)
10. Lower lip prominence	Labrale inferius to nose-chin tangent (li–E-line)
Reference lines	
11. V-angle	The angle formed by V-line and true vertical line (TV)
12. E-angle	The angle formed by E-line and TV
13. N-angle	The angle formed by N-line and TV

Registered NHP and estimated NHP are two common approaches to obtain the NHP for cephalometric analyses. However, these methods are subjective in nature, relying either on the perception of the orthodontists or of the patients. Although a previous study reported a strong correlation between registered NHP and estimated NHP,[10] the reliability of the NHP obtained from these two approaches is still in question. The idea of reorientating radiographs according to photographs to obtain the NHP has been suggested since 1957 and applied in previous studies.[9,20] Yet no study has investigated the reliability of such an approach nor proposed a reliable reference line for the reorientation. The results from the present study showed that all ICCs (intraclass correlation coefficient) between observers, methods, and sessions, except for the intermethod ICC for nasal angle, exceeded the minimal requirement for clinical use of a measurement technique. These findings lead us to conclude that using the standardized photographs to reorientate the radiographs for obtaining the NHP is a reliable method.

For the reorientation, the superimposing reference line is very important. The conventional reference lines (eg, V-line and E-line) are determined by landmarks that may change during orthodontic treatment[11] and are influenced by lip postures. Because the nose is a part on the face that appears not to be influenced by orthodontic treatment,[16] we introduced a new reference line named the nose-best-fit line (N-line). The N-line is an automatically drawn line through five

Table 2. Descriptive Statistics of Cephalometric Measurements

	Observer 1								Observer 2							
	R Session 1		R Session 2		P Session 1		P Session 2		R Session 1		R Session 2		P Session 1		P Session 2	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1. Total facial convexity	48.79	4.94	49.16	4.78	48.82	4.59	48.94	4.63	50.24	4.88	50.22	4.82	49.04	4.71	48.95	4.61
2. Total facial convexity (eg, nose)	17.35	8.66	17.13	8.72	16.62	8.02	16.28	8.09	16.78	8.94	16.54	8.79	16.02	8.07	15.87	8.06
3. Profile form	145.00	5.38	144.98	5.29	145.30	5.09	145.23	5.06	145.10	5.28	145.22	5.22	145.39	5.21	145.62	5.31
4. Convexity at soft pronasale	56.15	5.54	56.18	5.50	55.75	5.24	55.85	5.15	57.43	5.85	57.38	5.66	56.95	5.72	56.68	5.64
5. Nasal angle	21.43	3.41	21.88	3.48	22.10	3.29	22.34	3.27	22.96	3.27	23.08	3.58	22.62	3.30	22.71	3.22
6. Nose front angle	21.15	5.08	21.16	5.18	21.06	4.73	21.09	4.70	22.52	5.31	22.60	5.33	22.35	5.59	22.28	5.53
7. Depth of nasolabial curvature	−9.36	3.11	−9.36	3.20	−9.33	2.97	−9.41	3.02	−9.50	3.17	−9.48	3.20	−9.46	2.98	−9.50	3.00
8. Upper lip prominence	−3.14	3.92	−3.09	3.92	−3.23	3.82	−3.22	3.86	−2.85	3.95	−2.91	3.92	−3.30	3.86	−3.31	3.83
9. Lower lip prominence	−1.32	3.83	−1.19	3.87	−1.41	3.72	−1.36	3.76	−1.09	3.90	−1.12	3.89	−1.47	3.76	−1.45	3.76
10. Soft B to nose chin line	−5.71	2.51	−5.82	2.47	−5.65	2.35	−5.66	2.37	−5.66	2.46	−5.66	2.38	−5.72	2.35	−5.73	2.38
11. V-angle	7.83	5.72	7.62	5.59	9.00	6.42	8.85	6.44	7.50	5.78	7.44	5.70	8.58	6.45	8.07	6.23
12. E-angle	19.54	5.14	19.66	5.11	17.69	6.85	17.74	6.90	19.79	5.15	19.72	5.15	17.79	6.92	17.96	6.52
13. N-angle	36.01	6.61	36.04	6.69	37.60	7.35	37.68	7.22	37.13	6.55	37.25	6.47	38.80	7.95	38.01	7.83

R indicates radiograph, P, photograph.

Table 3. Reliability Coefficients (95% Confidence Intervals) as Measures for Interobserver, Intersession, and Intermethod Reliability for Measuring Different Facial Structures

		95% CI			95% CI			95% CI	
Variable	Interobserver	Lower Border	Upper Border	Intersession	Lower Border	Upper Border	Intermethod	Lower Border	Upper Border
1. Total facial convexity	.974	.960	.983	.978	.966	.986	.909	.863	.940
2. Total facial convexity (eg, nose)	.991	.986	.994	.992	.987	.995	.956	.932	.972
3. Profile form	.986	.978	.991	.989	.983	.993	.972	.957	.982
4. Convexity at soft pronasale	.953	.928	.970	.970	.954	.981	.906	.859	.938
5. Nasal angle	.930	.894	.954	.942	.911	.962	.836[a]	.762	.890
6. Nose front angle	.946	.917	.965	.962	.941	.976	.904	.856	.937
7. Depth of nasolabial curvature	.996	.994	.997	.996	.994	.997	.979	.967	.987
8. Upper lip prominence	.997	.995	.998	.998	.997	.999	.955	.931	.971
9. Lower lip prominence	.997	.995	.998	.998	.997	.999	.974	.960	.983
10. Soft B to nose chin line	.990	.984	.994	.992	.987	.995	.965	.946	.977
11. V-angle	.986	.978	.991	.987	.980	.992	.545[a]	.418	.661
12. E-angle	.994	.991	.996	.994	.991	.996	.617[a]	.495	.722
13. N-angle	.969	.952	.980	.977	.964	.985	.737[a]	.635	.817

[a] ICC lower than .900.

landmarks along the nasal bridge. Its measurement error is lower than that of a two-point line, such as the E-line or V-line. In the present study, the reliability of using the N-line as the reference line was tested and compared with the conventional reference lines (E-line and V-line). Our results indicated that the N-line is preferred over the V-line. Although the difference between the E-angle and N-angle in reliability coefficients is minor, an obvious advantage of the N-angle over the other two is that it is independent on lip postures. In the present study, the photographs and radiographs were made at the same session. We expect that the N-line might be a better reference line when the photograph and radiograph are taken at different sessions or at different treatment stages.

One limitation of the present study is the possible geometric distortions in both cephalograms and photographs related to the projective transformation. However, such distortions are almost inherent in two-dimensional imaging. The N-line, although not affected by orthodontic treatment, is subject to dorsal nasal growth. The ultimate solution to overcome these limitations would be three-dimensional imaging, which has shown numerous advantages and promising applications.[21,22]

CONCLUSIONS

- Reorientation of radiographs according to standardized photographs made at the NHP is a reliable and objective method to standardize the radiographs at the NHP for cephalometric analysis.
- The N-line is a reproducible and stable reference line for the reorientation. It is preferred over the V-line or even E-line, especially when the radiographs and photographs are taken at different sessions or at different treatment stages.

REFERENCES

1. Cooke MS, Wei SH. A summary five-factor cephalometric analysis based on natural head posture and the true horizontal. *Am J Orthod Dentofacial Orthop*. 1988;93: 213–223.
2. Cooke MS, Wei SH. The reproducibility of natural head posture: a methodological study. *Am J Orthod Dentofacial Orthop*. 1988;93:280–288.
3. Lundstrom A, Lundstrom F, Lebret LM, Moorrees CF. Natural head position and natural head orientation: basic considerations in cephalometric analysis and research. *Eur J Orthod*. 1995;17:111–120.
4. Moorrees CF. [Cephalometry and orthodontics after the introduction of Van Loon's ''cubus cranioforus'']. *Ned Tijdschr Tandheelkd*. 1988;95:461–467.
5. Houston WJ. Bases for the analysis of cephalometric radiographs: intracranial reference structures or natural head position. *Proc Finn Dent Soc*. 1991;87:43–49.
6. Moorrees CF. Growth and development in orthodontics. *Curr Opin Dent*. 1991;1:609–621.
7. Moorrees CF. Natural head position—a revival. *Am J Orthod Dentofacial Orthop*. 1994;105:512–513.
8. Cooke MS. Five-year reproducibility of natural head posture: a longitudinal study. *Am J Orthod Dentofacial Orthop*. 1990; 97:489–494.

9. Ferrario VF, Sforza C, Germano D, Dalloca LL, Miani A Jr. Head posture and cephalometric analyses: an integrated photographic/radiographic technique. *Am J Orthod Dentofacial Orthop*. 1994;106:257–264.
10. Peng L, Cooke MS. Fifteen-year reproducibility of natural head posture: a longitudinal study. *Am J Orthod Dentofacial Orthop*. 1999;116:82–85.
11. Bister D, Edler RJ, Tom BD, Prevost AT. Natural head posture—considerations of reproducibility. *Eur J Orthod*. 2002;24:457–470.
12. Jiang J, Xu T, Lin J. The relationship between estimated and registered natural head position. *Angle Orthod*. 2007;77: 1019–1024.
13. Usumez S, Orhan M. Reproducibility of natural head position measured with an inclinometer. *Am J Orthod Dentofacial Orthop*. 2003;123:451–454.
14. Lundstrom F, Lundstrom A. Natural head position as a basis for cephalometric analysis. *Am J Orthod Dentofacial Orthop*. 1992;101:244–247.
15. Raju NS, Prasad KG, Jayade VP. A modified approach for obtaining cephalograms in the natural head position. *J Orthod*. 2001;28:25–28.
16. Dvortsin DP, Sandham A, Pruim GJ, Dijkstra PU. A comparison of the reproducibility of manual tracing and on-screen digitization for cephalometric profile variables. *Eur J Orthod*. 2008;30:586–591.
17. Streiner DL. Starting at the beginning: an introduction to coefficient alpha and internal consistency. *J Pers Assess*. 2003;80:99–103.
18. Bland JM, Altman DG. Measuring agreement in method comparison studies. *Stat Methods Med Res*. 1999;8: 135–160.
19. Streiner DL, Norman GR. *Health Measurement Scales: A Practical Guide to Their Development and Use*. 3rd ed. New York: Oxford University Press; 2003.
20. Ferrario VF, Sforza C, Anderbegani A, Poggio CE, Dalloca LL. Relative position of porion and tragus in orthodontic patients. *Clin Anat*. 1995;8:352–358.
21. Damstra J, Fourie Z, Ren Y. Simple technique to achieve natural head position for cone beam CT scans. *Br J Oral Maxillofac Surg*. 2010;48:236–238.
22. Mah J, Yi L, Huang RC, Choo HR. Advanced applications of cone beam computed tomography in orthodontics. *Semin Orthod*. 2011;17:57–71.